Heavy Metal Contamination of Green Leafy Vegetables Cultivated in Residential Gardens in Enugu Urban, South East Nigeria

Joshua I. Ume[1]
Dean, Faculty of Natural and Applied Sciences,
Coal City University, Enugu, Nigeria

Chigozie B. Ichu[2] and Nnenna S. John[2]
Materials and Energy Technology Department,
Projects Development Institute (PRODA),
P.M.B.01609, Enugu, Nigeria

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ABSTRACT

The accumulation of some essential (Cu, Mn and Zn) and toxic metals (Cd and Pb) in cultivated vegetables- Telfairia occidental is (fluted pumpkin), Talinum triangulare (water leaf), Amaranthus viridis (green vegetable), and Vernonia amygdalina (bitter leaf) was investigated. The vegetables were cultivated in residential gardens in Enugu metropolis, the capital of Enugu State, South-East, Nigeria. Samples of these vegetables were randomly collected from three residential areas, dried, digested and analyzed for heavy metals using Buck 210VGP atomic absorption spectrophotometer. The relative abundance of the metals in the vegetables followed the sequence: Zn (2.28 mg/kg) > Mn (0.91 mg/kg) > Cu (0.45 mg/kg) > Pb (0.3 mg/kg) > Cd (0.05 mg/kg). The concentration levels of all the metals examined were within the FAO/WHO, Indian and the European Union (EU) recommended limits for metals in vegetables obtained from all the residential gardens. This implies that long term consumption of these vegetables does not pose any health risk to the inhabitants of Enugu urban. However, the presence of the metals indicates the gradual accumulation of heavy metals in leafy vegetables. Residential gardens should therefore not be sited close to main roads to avoid metal pollution from traffic emissions. Environmental authorities should prohibit the indiscriminate location of automobile repair shops contiguous to residential areas not only in Enugu Urban, but elsewhere across the country. The results showed that these vegetables are the good sources of essential trace metals.

Keywords: *Heavy metals, vegetables, residential garden*

1. INTRODUCTION

A lot of edible vegetables are grown all over Nigeria. The use of green leafy vegetables for the preparation of soups cuts across different cultures in Nigeria and other parts of West Africa [1, 2]. Heavy metals represent a range of contaminants that can be found on the surface and in the tissue of fresh vegetables. Prolonged human consumption of unsafe concentrations of heavy metals in foodstuffs may lead to the disruption of numerous biological and biochemical processes in the human body. Heavy metal accumulation gives rise to toxic concentrations in the body, while some elements (e.g., As, Cd and Cr) act as carcinogens. Others (e.g., Hg and Pb) are associated with developmental abnormalities in children [3].They are released into the environment through the soil, air and water. A recent study suggested that a possible source of heavy metals in residential gardens is residual irrigation water [4]. Organic and inorganic fertilizers have also been suggested as possible sources of heavy metals [4]. A similar study has postulated that agro-chemicals are contributors of heavy metals in residential gardens [6]. Wall paint has been indicated as another likely source. It contains heavy metals which are often washed off the walls by rain into the gardens [7]. Water and livestock feeds contain heavy metals as trace elements for growth and maintenance of health. Plants eventually take up heavy metals in manure applied in home gardens [8]. Enugu metropolis has vegetable gardens in many of its residential areas. These vegetables are grown for home consumption and for sale in the local market. Some of the agricultural practices among owners of home gardens in Enugu include the application of organic manure and inorganic fertilizer. In their bid to combat pests and diseases, they occasionally use agro-chemicals. Due to the fact that some of the gardens are close to highways, it is suspected that automobiles are also a source of heavy metal contamination. Although some of these metals are essential, the metals considered in this study are toxic to humans, even at relatively low levels [9, 10-15]. The objective of this paper therefore is to determine the levels of Cu, Mn, Zn, Cd and Pb in green leafy vegetables cultivated in Enugu residential gardens with comparisons to maximum contaminant levels.

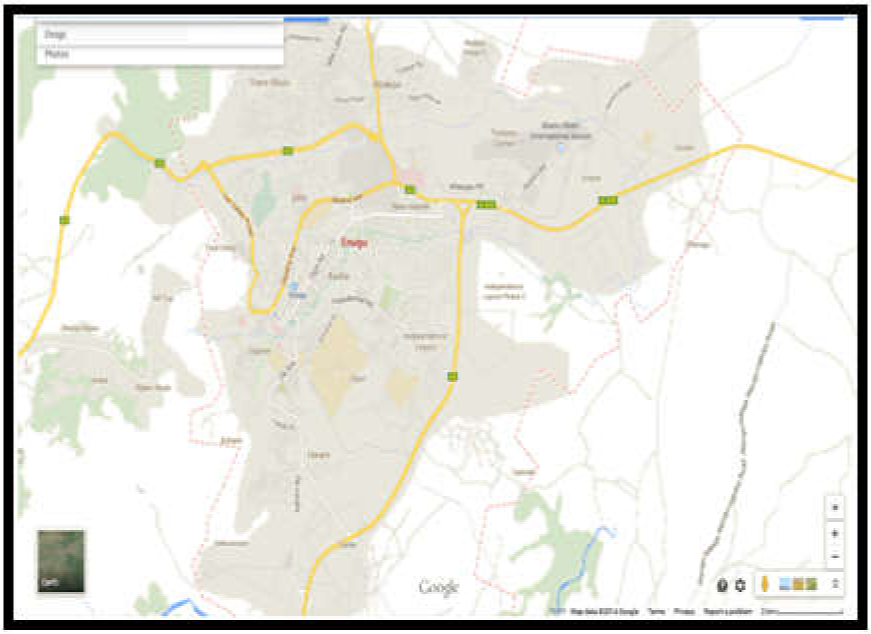

Figure 1.1: Map of Enugu Urban

2. MATERIALS AND METHODS

Chemicals of analytical grade purity and distilled water were used in all the analysis. The glass wares and plastic containers used were washed with detergent solution followed by (20% v/v) nitric acid and then rinsed with tap water and finally with distilled water. Standard solutions of the metal salts and other reagents were prepared and employed as needed.

2.1 Study Area

Enugu is the capital city of Enugu State, south eastern Nigeria. The state was created in 1991 from the old Anambra State. Enugu state is located within latitude 6° 00' N and 7° 00' N and longitude 7° 00' E and 7° 45' E. It is called the Coal City State because of the discovery of coal in a commercial quantity in Enugu Urban in 1909. Enugu subsequently became the capital of East Central State of Nigeria. Some of the important towns in the State are Enugu Urban, Oji, Udi and Nsukka Urban. The State shares borders with Abia State and Imo State to the south, Ebonyi State to the east, Benue State to the northeast, Kogi State to the northwest and Anambra State to the west. Enugu State is made up of 17 local government areas. These include Igbo Eze North, Igbo Eze South, Udenu, Nssuka, Isi Uzo, Uzo Uwani, Igbo Etiti, Udi, Enugu East, Enugu North, Enugu South, Ezeagu, Nkanu West, Nkanu East, Oji-River, Awgu and Aninri local government areas. Enugu Urban which is the study area is made up of Enugu East, Enugu North, and Enugu South, as depicted in Figure 1.1. Enugu Urban with a population of 722,664 [16] is also located within latitude 6.24°N and 6.30°N and longitude 7.27°E and 7.32°E. It is an hour's drive from Onitsha, one of the biggest commercial cities in Africa and two hour's drive from Aba, another very large commercial city, both of which are trading centers in Nigeria. Enugu Urban shares boundary with Igbo Etiti and Isi-Uzo Local Governments in the north, Udi local Governments in the west, Nkanu West Local Government in the south and part of Nkanu East Local Government Area in the east. There are 18 prominent residential areas in the metropolis. These are Abakpa, Trans-Ekulu, Nike, GRA, Ogui, Asata, New Haven, Obiagu, Ogbete, Iva valley, Independence Layout, Achara Layout, Ugwuaji, Maryland, Awkunanaw, Uwani, Agbani, and Coal Camp. Enugu Urban is the most developed urban area in Enugu state [17].

2.2 Sample Collection and Preparation

Samples of each vegetable: *Telfairia occidentalis* (fluted pumpkin), *Talinum triangulare* (water leaf), *Amaranthus viridis* (green vegetable), and *Vernonia amygdalina* (bitter leaf) were collected at random from residential gardens in three representative residential areas of Enugu Urban: Uwani (Enugu South), Asata (Enugu North) and Abakpa (Enugu East). The collection of the vegetables was carried out in October 2013. The samples were collected and stored in clean polyethylene bags. The vegetables were washed first with tap water and then with distilled water to remove any possible foliar contaminants, such as pesticides, fertilizers, dust or mud. The leaves of the vegetables were then cut into small pieces using a stainless steel knife. The samples were air dried in three days on a clean aluminum sheet to remove excess moisture. The samples were then dried in a dust free, hot air oven at 105°C to a constant mass. The samples were blended with an electric blender and subsequently screened with a 250 mesh sieve. The method described by Deeba, F. et.al. [18] used for the digestion of the plant samples with slight modifications. 1 g of each vegetable sample from each location, was weighed and placed in a 50 cm^3 beaker, thereafter, 10 cm^3 (2:1) mixture of concentrated nitric acid (HNO_3) and per chloric acid ($HClO_4$) by volume were added to digest the sample. The beaker was heated at a moderate temperature of 110°C on a hot plate for 1 hr in a fume hood until a clear digest was obtained. The digest was allowed to cool, filtered with a Whatman Nọ 1 filter paper into 100 cm^3 standard volumetric flask and made up to the mark with distilled water. The samples were stored in airtight plastic containers for elemental analysis with Buck Model 210 VGP atomic absorption spectrophotometer.

Table 2.1: Distribution of vegetable samples collected per site.

Site	Number of samples			
	Fluted Pumpkin	Green Leaf	Water Leaf	Bitter Leaf
Uwani	3	2	2	3
Asata	3	2	2	3
Abakpa	3	2	2	2

2.3 Sample Analysis

Analytical reagent grade chemicals and distilled water were used for preparing all solutions. Stock solutions containing 1000 mg/kg of the analytes were prepared from nitrate salts of Cd, Cu, Mn, Pb and Zn. Working standard solutions were prepared by appropriate dilutions of the stock solutions. Blank determinations were run by using the same reagents in equal quantities as described in the analysis procedure throughout the analysis. The concentrations of the metals in each sample digest were determined with a Buck Model 210 VGP flame atomic absorption spectrophotometer, with an air-acetylene flame. Metal contents were calculated by comparison with the standard curves of the respective metals. Hollow cathode lamps having resonance lines at 326.1, 327.4, 279.5, 283.3 and 307.6 nm were used as radiation sources for the determination of Cd, Cu, Mn, Pb and Zn, respectively. Lamp intensity and band pass were used according to the manufacturer's recommendations. Acetylene and air flow rates were 5 and 20 L min^{-1}, respectively, for all the elements.

3. RESULTS AND ANALYSIS

Table 3.1: Average heavy metal concentration (mg/kg) in four vegetables grown in Enugu Urban.

Metal	Max. permissible limits (mg/kg)				Concentration of Metal in Vegetable (mg/kg)			
	FAO/WHO	Indian	EU	Site	FP	WL	GL	BL
Cu	40	30	_	Uwani	0.10	0.42	0.20	0.10
				Asata	0.11	0.25	0.30	0.30
				Abakpa	0.45	0.22	0.35	0.30
Mn	500*	_	_	Uwani	0.05	0.83	0.15	0.25
				Asata	0.35	0.54	0.18	0.16
				Abakpa	0.91	0.43	0.26	0.17
Zn	60	50	_	Uwani	0.78	2.28	1.93	0.73
				Asata	0.78	1.26	0.89	1.68
				Abakpa	0.59	0.72	0.89	0.39
Cd	0.02	1.5	0.2	Uwani	0.03	0.05	0.04	0.02
				Asata	0.02	0.03	0.03	0.02
				Abakpa	0.03	ND	0.02	ND
Pb	5.0	2.5	0.30	Uwani	ND	0.3	ND	0.1
				Asata	0.03	0.3	ND	0.2
				Abakpa	ND	ND	0.1	ND

FP= Fluted Pumpkin, WL= Water Leaf, GL= Green Leaf, BL=Bitter Leaf, ND= Not Detected
* (FAO/WHO, 2001) FAO/WHO (Codex Alimentarius Commission) (2001). Food additives and contaminants. Joint FAO/WHO Food Standards Program; ALINORM 01/12A:1-289.

Table 3.2: Mean values of the heavy metals level in each of the vegetable samples.

Vegetables	Metals (mg/kg)				
	Cu	Mn	Zn	Cd	Pb
BL	0.25	0.19	0.93	0.02	0.15
FP	0.22	0.43	0.72	0.03	0.30
GL	0.28	0.20	1.24	0.03	0.10
WL	0.30	0.60	1.42	0.04	0.30

The average concentrations and the mean values of heavy metals in the fluted pumpkin, water leaf, green leaf and bitter leaf samples from Uwani, Asata and Abakpa Nike are shown in Tables 3.1 and 3.2. Pb was the least observed metal in all the samples investigated. It was present in only 50% of the samples with concentrations that are within safe limits. Cd on the other hand had the smallest concentration in all the samples. It was not detected in water leaf and bitter leaf in Abakpa. It was however detected in water leaf and green leaf in Asata and in fluted pumpkin from Abakpa. Its concentration in all the vegetables is within limits. The presence of Cd in these residential areas is due to pollution from traffic emissions, dumping of automobile waste products along the road, unregulated parking of motor vehicles and indiscriminate repair of broken down vehicles in this area. Similarly, its detection in the leaves is due to the proximity of these gardens to the main road. The concentrations of Zn, Cu and the other metals in all the vegetables are all within the safe limits of FAO/WHO, India and EU [19-21]. The mean values of Zn were the highest in all the vegetables.

3.1 Fluted Pumpkin

The maximum concentrations of heavy metals decreased in the order Mn (0.91 mg/kg) > Zn (0.78 mg/kg) > Cu (0.45 mg/kg) > Cd (0.03 mg/kg), Pb (0.03mg/kg). In a previous work done in Abakaliki urban, South East Nigeria, the mean concentration followed the trend: Pb (0.202 mg/kg) > Zn (0.022 mg/kg) > Cd (0.002 mg/kg) [22]. In a related study, the accumulation of heavy metals in fluted pumpkin from residential areas in Lagos, south west Nigeria, followed a similar trend: Cu (0.326 mg/kg) > Zn (0.416 mg/kg) > Cd (0.002 mg/kg) > Pb (0.002 mg/kg) [23]. In another study in different locations in Lagos, however, the mean concentration of Cd in the vegetable was higher: (Ikeja, 5.233 mg/kg > Ikoyi, 3.100 mg/kg > Bariga, 0.817 mg/kg) [24]. These higher concentrations of Cd in Lagos may be attributable to the high industrial activity in that city.

3.2 Water Leaf

The maximum concentrations of heavy metals in water leaf from all three sites decreased in the order Zn (2.28 mg/kg) > Mn (0.83 mg/kg) > Cu (0.42 mg/kg) > Pb (0.3 mg/kg) > Cd (0.05 mg/kg). Previous studies showed that the concentrations of heavy metals in water leaf from Abakaliki urban, another south eastern Nigeria city follow a similar trend: Zn (0.144 mg/kg) > Pb (0.101 mg/kg) > Cd (0.009 mg/kg) [24]. The trend is akin to the results obtained from Enyigba Lead Mine in Ebonyi State, south east Nigeria): Zn (0.174 mg/kg) > Pb (0.112 mg/kg) > Cd (0.011 mg/kg) [22] and from vegetables gardens around a construction site in Uyo (South South, Nigeria): Zn (2.340 mg/kg) > Pb (0.003 mg/kg) and Cd (0.003 mg/kg) [25]. These data are consistent with the results of the present investigation: a low accumulation of Pb and Cd and a high accumulation of Zn. Water leaf accumulated higher levels of heavy metals compared to the other vegetables.

3.3 Green Leaf

The maximum concentrations of heavy metals in green vegetable from all three sites decreased in the following order: Zn (1.93 mg/kg) > Cu (0.35 mg/kg) > Mn (0.26 mg/kg) > Pb (0.1 mg/kg) > Cd (0.04 mg/kg). This trend is similar to the accumulation of heavy metals in washed green vegetable grown along major highways in Lagos: Zn (23.26 μg/g) > Cu (6.50 μg/g) > Pb (5.75 μg/g) [26]. In Owerri, Umuagwo and Ohaji, south east Nigeria, the accumulation was Pb (1.60 μg/g) > Cd (0.27 μg/g) [27]. These results are similar to those obtained in the present study: a low accumulation of Cd and Pb and a high accumulation of Zn and Cu.

3.4 Bitter Leaf

The maximum concentrations of heavy metals in bitter leaf decreased in the following order: Zn (1.68 mg/kg) > Cu (0.30 mg/kg) > Mn (0.25 mg/kg) > Pb (0.20 mg/kg) > Cd (0.02 mg/kg). This result is similar to the metal concentrations in bitter leaf from residential areas in Lagos: Cu (0.344 mg/kg) > Zn (0.092 mg/kg) > Cd (0.006

mg/kg) > Pb (0.001 mg/kg) [1]. The low accumulation of Cd and Pb was also observed in bitter leaf from Abakaliki Urban: Zn (0.072 mg/kg) > Pb (0.421 mg/kg) > Cd (0.007 mg/kg) [22].

4. CONCLUSION

The levels of Zn, Cu, Mn, Cd and Pb in green leafy vegetables grown in residential gardens in Enugu Urban have been investigated. Zn was the highest accumulated metal in the investigation. Water leaf grown in Enugu residential gardens had the highest bio-accumulation of heavy metals among the vegetables studied. The concentrations of the heavy metals in these vegetables were within the permissible limits of FAO/WHO, Indian and EU standards. This implies that long term consumption of these vegetables does not pose any health risk to the inhabitants of Enugu.

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